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FIBER-REINFORCED METALS AND ALLOYS

IITRI-B241-7

(Bimonthly Report No. 7)

April 4 to June 4, 1963

for

Chief, Bureau of Naval Weapons
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IIT RESEARCH INSTITUTE

FIBER-REINFORCED METALS AND ALLOYS

I. INTRODUCTION

This is the seventh bimonthly report on IITRI Project No. B241, entitled "Fiber-Reinforced Metals and Alloys," and covers the work done in the period April 4, 1963 to June 4, 1963.

The work performed in the past, under Bureau of Naval Weapons sponsorship, developed some basic criteria for the production of fiber-reinforced composites, and suggested that fiber reinforcement might be a practical way of making metal composites with high strength-to-weight ratios and high elastic moduli. Accordingly, a study of the strengthening effects of beryllium fibers in metal matrices is being made. The composites are prepared either by mixing powder matrix material with the beryllium fibers and then hot extruding the green compact or by casting and extruding as described in earlier reports. Present research effort is concerned with composites of beryllium fibers with aluminum powder and with aluminum alloy powder.

II. RESULTS AND DISCUSSION

Previous results on as-extruded composites (ARF-B241-6, February 4 to April 4, 1963) indicated that additions of up to 50 volume per cent of beryllium fibers to type 1100 (unalloyed) aluminum raised the strength of the composites to about twice that of the beryllium-free aluminum, but showed no dependence of tensile strength on beryllium content. At the higher beryllium contents, severe surface cracking was common on the extrusions, and all efforts to overcome this cracking were unsuccessful. Sometimes minor surface cracks were found on extrusions containing 10 or 30 volume per cent beryllium fibers or powder, especially at the higher extrusion ratio. It was necessary to machine off these surface cracks before the composites were tensile tested. This raised the question of whether the test data tabulated in the last report might be misleadingly lower than the true tensile values because of minute cracks in the specimens. To check on this point, two composites--one of 10

volume per cent beryllium fibers with 1100 aluminum powder, and the other of 10 volume per cent beryllium powder (-325 mesh) with 1100 aluminum powder--were first hot extruded through a 6.5:1 reduction. In this condition the composites were free from cracks. The bars were then hot-rolled to 1/8 in. thick strip. Careful examination showed no surface cracks, so tensile specimens were cut and tested. The results were: a UTS of 16,200 psi in the fiber compoties, and a UTS of 21,400 psi in the powder composite. These values compare favorably with the results given in Tables I and II, respectively, in the previous Report, and would seem to indicate that the data in the Sixth Report are true values.

Additions of up to 50 volume per cent of beryllium powder to 1100 aluminum gave more consistent results than did the beryllium fibers; the tensile strength increased linearly with increasing beryllium powder content, but again the strength increases were not substantial.

Further metallographic examinations of the above composites confirmed the previously reported view that a third, hard black phase tended to form in the beryllium fiber-1100aluminum composites with deleterious effects. Moreover, the beryllium fibers tended to assist the formation of this black phase by coagulating into massive agglomerates, even after only a light extrusion. Figure 1 shows parts of two such masses in a 10% beryllium fiber-1100 aluminum composite, extruded through a 6.5:1 ratio. This can be compared to Figure 2, which shows a 10% beryllium powder-1100 aluminum composite after the same deformation. The more consistent tensile properties, of the latter, obviously reflect the uniform distribution of its beryllium particles, and the absence of a third hard phase.

Composites of beryllium fibers and beryllium powders with a heat-treatable 7075 aluminum alloy (Table IV of previous Report) showed more promise of higher strengths than the straight aluminum matrices, though, again, there was no apparent dependence of UTS on beryllium content. In the as-extruded condition the 7075 alloy is in its solution-treated state. A low-temperature aging treatment should harden it considerably. Results on some 10 volume per cent fiber and powder

compacts in the as-worked and heat-treated conditions are given in Table I. The rolled materials were made in the same manner as the 1100 aluminum composites, i. e., from lightly extruded composites. Heat treatment consisted of a solution treatment at 850°F, followed by water-quenching, then aging at 250°F for 18 hours.

Apart from an anomalous result at the head of the table, where the heat-treated -100 mesh powder compact is weaker than the extruded material, the results indicate a general improvement in strength on heat-treatment. The biggest increases occur in the beryllium powder composites, the greatest advantage being with the -325 mesh powder composite. Further tests will be made with -325 mesh powder composites of increasing beryllium content. If it is found that such increases do not raise the tensile strengths of the composites considerably above that of the sintered, rolled, and heat-treated matrix material alone (~76,000 psi), then tests on these composites will be discontinued and new approaches will be tried.

Metallographic examination of those composites based on 7075 alloy show them to be very similar to those based on 1100 aluminum (Figures 3 and 4). Very little deformation of the beryllium particles occurs during hot working of the composites, and hence the beryllium particles display little of a fibrous nature. Fracture in these composites appears to occur both across and around the beryllium particles (Figures 5 and 6), and the materials show little ductility. The largely interfacial nature of the fracture indicates a weak bond between the two constituents.

III. FUTURE WORK

The beryllium fibers used in the work to date have not proved satisfactory, and this may be entirely due to the irregular shape of fibers. However, further work will be carried out on beryllium fiber and powder composites. One point requiring clarification is the influence of beryllium content on the tensile strength of the fine beryllium powder-7075 alloy composites. Different matrix alloys will also be investigated. In this respect, some aluminum-titanium and aluminum-titanium-vanadium alloys are now being made.

IV. LOGBOOKS AND CONTRIBUTING PERSONNEL

The data herein are recorded in Logbooks No. C11179 and C-13168. N. M. Parikh, K. Farrell (Associate Metallurgist), and M. Malatesta (Assistant Experimentalist) contributed to this program.

Respectfully submitted,

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jcr

Neg. No. 25148 x 160

FIG. 1

Cross-section of a lightly-extruded, 10% beryllium fiber-1100 aluminum composite, showing agglomerated beryllium fibers and hard, black phase.

Neg. No. 25149 x 160

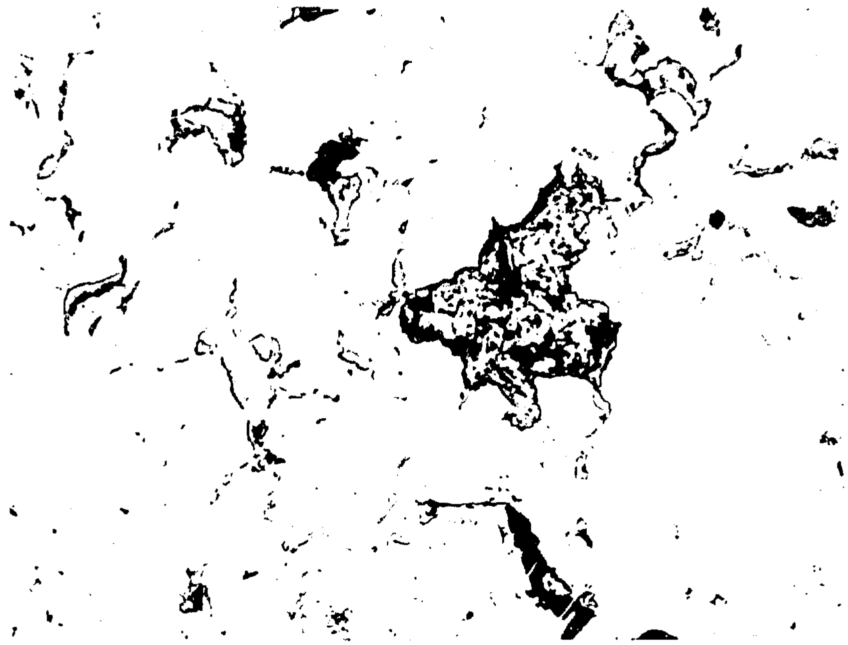
FIG. 2

Cross-section of a lightly-extruded 10% beryllium powder (-325 mesh)-1100 alumimum composite.

TABLE I

INFLUENCE OF HEAT TREATMENT OF THE TENSILE STRENGTHS OF SOME BERYLLIUM POWDER AND FIBER COMPOSITES WITH 7075 ALUMINUM ALLOY

Composition vol% Be	Extrusion Temp., °F	Extrusion Ratio	Rolling Temp., °F	Condition	Tensile Strength, psi
10% powder (-100 mesh)	850	40:1	---	As-extruded Heat-treated	48, 200 36, 800
10% fibers	850	18:1	---	As-extruded Heat-treated	45, 400 49, 800
10% fibers	800	6. 5:1	800	As-rolled Heat-treated	43, 500 57, 800
10% powder (-100 mesh)	800	6. 5:1	800	As-rolled Heat-treated	40, 800 63, 500
10% powder (-325 mesh)	800	6. 5:1	800	As-rolled Heat-treated	50, 300 67, 500



Neg. No. 25146 x 160

FIG. 3

Cross-section through a lightly-extruded 10% beryllium fiber-7075 alloy composite, showing agglomerated fibers.

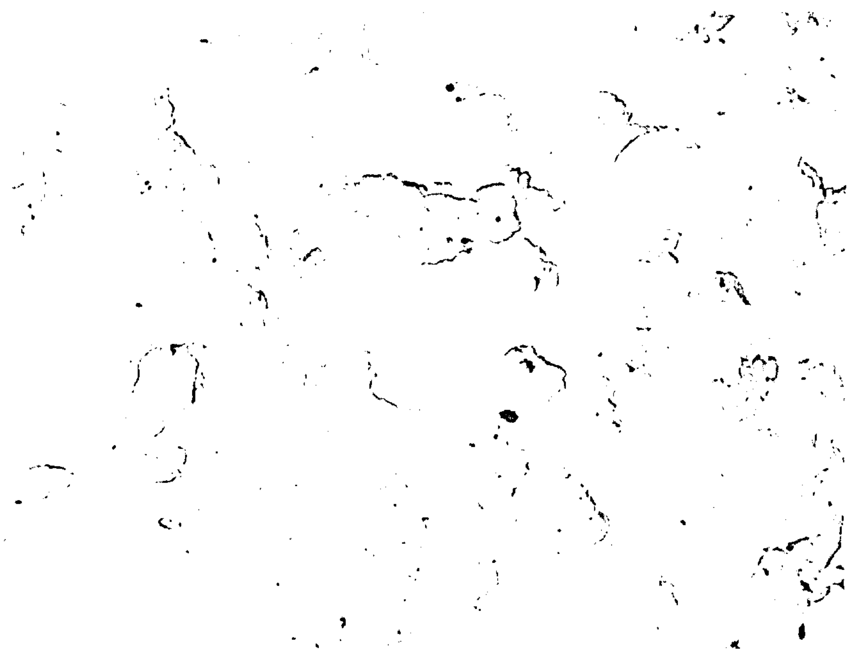


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FIG. 4

Cross-section through a lightly extruded 10% beryllium powder (-325 mesh)-7075 alloy composite.

Neg. No. 25143 x 160

FIG. 5

Fracture edge of a hot-rolled 10% beryllium powder (-100 mesh)-7075 alloy composite showing fracture path running around and across beryllium particles

Neg. No. 25145 x 160

FIG. 6

Fracture edge of a hot-rolled 10% beryllium powder (-325 mesh)-7075 alloy composite showing fracture path running around and across beryllium particles.